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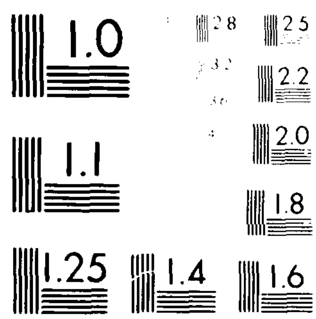
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THE EFFECTS OF HIGH VELOCITY VARIABLE MASS PROJECTILES ON THE MAXILLOFACIAL COMPLEX (U)

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WILLIAM R. POSEY, COL, DC
DUANE E. CUTRIGHT, COL, DC, EMERY A. RUSSELL, JR. COL, DC
JOHN F. NELSON, COL, DC
U. S. ARMY INSTITUTE OF DENTAL RESEARCH
WASHINGTON, D. C. 20012
V. ROBERT CLARE, et al*
CHEMICAL SYSTEMS LABORATORY
ABERDEEN PROVING GROUND, MARYLAND 21010

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Introduction

The weaponry used against the United States Soldiers in the Vietnam conflict produced wounds which required modification of numerous accepted conventional treatment methods and also resulted in new methods of treatment. However today with the scenarios predicting the appearance of new small high velocity missiles, these treatment methods may be outmoded. Therefore, if surgical treatment capabilities and doctrine are to keep pace with these new advances in combat arms, new baseline data must be found through controlled studies to determine the morphology of wounds caused by such projectiles and to establish and disseminate treatment data which will provide optimum treatment to the soldier.

The inventories of fielded weapons of many nations include anti-personnel weapons and devices with the capability of hurling projectiles of varying sizes (2-25 grains) at peak velocities which exceed 8,000 feet per second (fps). Due to the extremely high energies and small sizes of these missiles, they produce entirely different wounding patterns as compared to the so called "conventional" weapons, such as used in Vietnam, which imparted speeds usually not exceeding 3500 fps. Due to this lack of knowledge concerning wound production and morphology, morbidity and mortality, it is imperative to generate baseline data on such wounds for the combat casualty management teams. Such information will enable these teams to establish methods and

doctrine for casualty management usable in future conflicts.

The maxillofacial complex is the only vital area of the body totally unprotected during combat and therefore highly subject to injury by high velocity missiles in any conflict.

History of Combat Maxillofacial Wounds

A review of the literature suggests that most advances in the surgical treatment of wounds have historically ocurred during periods of combat or armed conflict. Although gun-powder-propelled missiles have been used in combat for hundreds of years, it was not until the Napoleanic Wars in the late eighteenth century that wide debridement of wounds was initiated (Schwartz, 1944). This debridement was probably quite crude because, as far as can be ascertained from the literature, it was not until the Crimean War (Mid-19th Century) that recorded observations are available concerning a very important principle of debridement. That is, the extensive vascular supply to the maxillofacial region makes debridement of this region basically different from that of other areas (Macleod, 1862). This principle, obviously, is just as valid today as it was then.

As one would suspect of trench warfare, World War I produced a high number of severe maxillofacial injuries; the trench protected the body, the helmet protected the head, and the face was the major point of exposure (Converse, 1942). He further attributed the severity of these wounds to machine gun bullets and bomb fragments hitting and penetrating the tissues of the face. His observations were substantiated by data from the Army Surgeon General. In 8,000 facial injuries to the American Expeditionary Forces, 3,000 proved to be fatal (Blair, 1943). This high incidence of facial wounds was probably the driving force behind the sudden surge in the development of new maxillofacial treatment techniques. According to Kelly, 1977, (a), "This was the first time in recorded history that a universal attempt had been made to accomplish reconstructive surgery in patients who had sustained maxillofacial battle injuries."

There is a paucity of reports concerning the development of new and better diagnostic procedures, surgical techniques, and other methods for improved care of patients with maxillofacial injuries resulting from conventional missiles from World War I (WWI) to World War II (WWII). In fact, in spite of the advances made in the management of maxillofacial wounds during WWI, the importance of debridement was again overlooked at the beginning of WWII; however, this serious error in the proper surgical management of the conventional maxillofacial injury was soon corrected (Kelly, 1977 [b]).

A review of 2600 KIA's in Vietnam revealed that 46.6% had head and neck wounds. In Maughon's (1970) discussion, he stated "...the large number of head and neck wounds (46.6%) was impressive, especially those where a single wound or small fragment was the only

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apparent injury." When surgical treatment requirements are considered for the combat environment, the other statistics of wound categories are equally significant. Of the 303,469 war related injuries during the period 1 January 1965 through 31 March 1973, 10-15% were of the maxillofacial complex (Tinder, et al., 1969).

The importance of information concerning combat casualty management of maxillofacial injuries becomes even more significant when the following quotes from Emergency War Surgery NATO Handbook (1975) (a,b) are considered.

"The number of high-velocity missile wounds has been increasing in succeeding wars of modern times; the increase resulted from the use of high-velocity small arms and automatic weapons together with reintroduction of the Claymore mine which, upon detonation, emits numerous small spherical missiles at high velocity... Artillery, mortar, grenade and mine fragments are irregular and vary not only in size and shape but also in velocity. Both bullets and fragments are considered to be primary missiles. Secondary missiles include shell wadding, clothing, building material, rocks, and other objects which are converted into wounding missiles by the effects of the primary missile." In the maxillofacial area secondary missiles also must include tooth fragments such as enamel, dentin and bone. "The type of wound which results from a missile may be a simple contusion or a penetrating or perforating wound. In a penetrating wound the kinetic energy is dissipated wholly into the tissues. In a perforating wound, the amount of energy imparted to the tissues is the difference between the kinetic energy remaining at the point of exit and that present at the wound of entrance. The density of the tissues struck determines the nature of the wounds as described above. Kocher demonstrated in 1876 that tissues which contained large quantitites of water (body fluids) were most severely damaged , and Daniel, in 1944, correlated the severity of high-velocity wounds with the specific gravity of the tissue involved. Muscle is severely damaged because of its relatively high homogenous density. In contrast, the lung sustains less extensive local destruction because of its low density, resulting in absorption of less energy and a small temporary cavity. Tissues of varying density, such as fascia or bone, may divert the direction of the missile, resulting in bizarre wound tracts." This quote is particularly applicable to the maxillofacial area with its increased blood supply, covering muscle and bony framework.

Large projectiles are not necessary to produce incapacitation. Small projectiles at higher velocities can create as much or more incapacitation, the controlling factors being variations of velocity and projectile size. Recent data concerning foreign anti-personnel combat arms reveals that hand grenades, mines and other weapons are carefully designed and fabricated to deliver the largest numbers of small fragments in the 2 to 50 grain size at very high velocities.

In an excellent study utilizing gelatin blocks, different sized spheres, and velocities up to 2.09 Km/second (Charters and Charters, 1976), it was noted that "smaller projectiles will give up their energy during penetration in a shorter distance than will larger projectiles of equal energy." To gain a better appreciation of the development of a specific wound morphology, one of their observations is quoted as follows: "The tissue moves spherically away from the projectile, opening up a temporary wound cavity that is characteristic of high-velocity gunshot wounds. After the cavity reaches its maximum volume, the tissue rebounds, collapsing into the cavity, leaving a narrow residual wound track. The magnitude of the temporary wound cavity is dependent upon the energy imparted by the projectile during penetration of the tissue, since the energy decreased exponentially with the distance penetrated."

When wounds of hard and soft tissues are evaluated (as opposed to soft tissue only), major implications and complications arise (Clemedson, 1973; Kabkob and Slepchenko, 1979). The striking or wounding projectile may be the primary injuring missile, but it may be only one of many contributors to the morphology of the wound. High velocity projectiles, striking bone and/or teeth, produce numerous secondary missiles, all of which have the potential of high velocity movement within the tissue. Obviously, any or all of these secondary missiles can produce extensive and distant damage in addition to the damage of the positive and negative pressures resulting from the high velocity of the primary missile. It is the combination of the effects of the primary and the secondary missiles that are responsible for the different wound morphology produced by high velocity missiles. It is also this myriad of presentations in the maxillofacial region that tests the surgeons diagnostic acumen, surgical knowledge and techniques. How critical rapid accurate diagnosis and subsequent surgical management of maxillofacial wounds becomes is evident when one considers the close proximity to the maxillofacial complex of numerous vital structures, such as sight, smell, hearing, taste, airway, vascular networks, and the brain. The implications of future social stigma due to facial injuries must also be considered by the military combat casualty management team at the earliest opportunity.

Purpose of Study

This study, using controlled conditions, was designed to provide new data on potential wound morphology from high velocity projectiles of varying sizes by using simulants for human maxillofacial hard and soft tissues. The validity of studying wound morphology in gelatin blocks has again recently been substantiated by Dubin who in 1974 showed that there were remarkable similarities between gelatin and freshly excised pig tissues. The data generated in this study will answer the following questions and provide a more meaningful base on which to improve and develop effective diagnostic procedures,

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surgical techniques, and enhance total patient care:

What are the effects of high velocity variable size projectiles on the human maxillofacial complex? What is the morphology of wounds created at these very high energy levels? Are current diagnostic and surgical techniques adequate to provide optimum care for injuries caused by varying sized projectiles impacted at speeds in excess of 1,750 m/s (5250 fps)? Will the induced morphology necessitate modifications of existing surgical techniques or must new ones be developed?

A final justification of this study can be found in the following quote from "Emergency War Surgery NATO Handbook" (c): "From the medical standpoint, the surgeon must know the wounding capacity of the weapons to assist in evaluating the extent of injury to achieve the most effective therapy".

Methods and Materials

In order to study tissue changes resulting from the impaction of high velocity missiles it was necessary to fabricate tissue simulants for the high velocity study. These simulants were composed of human skulls, purchased from Wards Natural Scientific Establishment, Inc., P.O. Box 1712, Rochester, New York 14603, infiltrated by and imbedded in Pharmagel "A" type gelatin to simulate the soft tissues of the head. These tissue simulants in block form were then carved to closely approximate the human facial conturs (see Figure #8).

Impact velocities were achieved via a precisely fabricated launching device utilizing large capacity brass powder cases in high pressure steel chambers threaded to long barrels to gain velocities of 5000 feet per second (fps) or higher, utilizing 2, 7, 16 and 55 grain missiles. These missiles were fabricated in both spherical and cylindrical shapes from high carbon steel rods or special bronze alloys. These missiles and the actual firings were carried out in a special room in Chemical Systems Laboratory facilities at Aberdeen Proving Ground, Maryland.

This study consisted of a total of sixteen (16) firings with the following missile sizes:

55 grain	3 shots
16 grain	3 shots
7 grain	6 shots
2 grain	4 shots

Muzzle to target distance varied from 4.2 meters to 4.47 meters. Muzzle velocities varied from a low of 5637 fps to a high of 7340 fps.

Each firing and impact was recorded by high speed cinemaphotography at 3,000 and/or 30,000 frames per second to study the displacement, deformity and extent of tissue alteration during impaction,

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penetration or perforation.

Immediately post-impaction, the gelatin-impregnated skulls and any fragments were assembled, studied and photographed in order to assess tissue damage.

Findings

The following descriptions of selected firings are representative examples of the types of wound morphology found in this study.

Fifty-five grain missile at 6144 fps - impacted into a gelatin block measuring 5"X6"X15" and weighing 17 pounds.

The block was split into 3 pieces along nearly its entire length. As the imparted energy of the missile was expended, the cavity in the gelatin block opened to approximately 1½ times its original size. This created a negative pressure which pulled fragments of the timing grid and other nearby debris into the wound, figure 1.

Fifty-five grain bronze cylinder fired at 6,104 fps impacted into the right ramus of the mandible.

The right and left bodies of the mandible were completely avulsed. Numerous small fragments of bone and teeth were scattered throughout the gelatin block, figure 2. Both the right and left zygomatic arches were separated at the suture lines. Much of the maxillary tooth bearing bone was also avulsed, although the anterior maxillary process was displaced but still present in the block. The extent of involvement of the facial skeleton was only fully revealed after partial removal of the gelatin, figure 2. After removal over 180 bone and tooth fragments were found scattered throughout the oral cavity and soft tissue, figure 3.

Sixteen grain missile impacted at the midline (symphysis) of the mandible at 5746 fps.

The entire anterior mandible was avulsed. Also all of the maxillary teeth and part of the maxilla were avulsed. The entire anterior maxilla was displaced and the floor and wall of the orbit were similiarly fractured and loosened, figure 4. Careful removal of the gelatin revealed many secondary missiles had spread into the foramen magnum and across the base of the skull, figure 5.

Sixteen grain missile impacted at 7340 fps on the right Zygomatic Complex. Exit was at angle of left mandible.

The entire maxillofacial complex and base of skull were fractured and displaced. The entire mandible and much of the maxillary tooth bearing bone were missing, figures 6 and 7.

Seven grains impacted at 5637 fps into the zygomatic arch.

The zygoma, wall of the orbit and right condyle were all fractured, figure 8. The wound tract (figure 9) traversed through the oral cavity to the left mandible ramus where the missile stopped. The left mandible was not fractured. The extent of damage was not easily ascertained until the gelatin was removed. This revealed multiple fragmentation of both the maxilla and mandible, figure 10. Many small

Figure 1: Fifty-five grain missile impacted at 6144 fps.
The block was split into 3 pieces and the resulting cavity and negative pressure sucked in surrounding debris. Arrows.

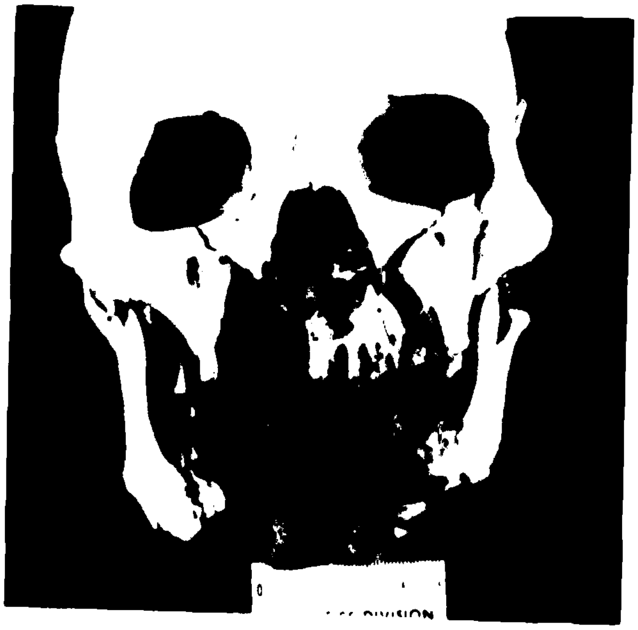

Figure 2: Fifty-five grain bronze cylinder impacted into symphysis of the mandible at 6109 fps.
Anterior view showing avulsion of anterior mandible and much of the maxilla. Hundreds of secondary missiles of various sizes can be seen A. Suture separations are visible at B.

Figure 3: Fifty-five grain bronze cylinder impacted into symphysis of the mandible at 6109 fps. Composite of bone and tooth fragments found when the gelatin was removed. Fragments smaller than 2-3 millimeters are not included.

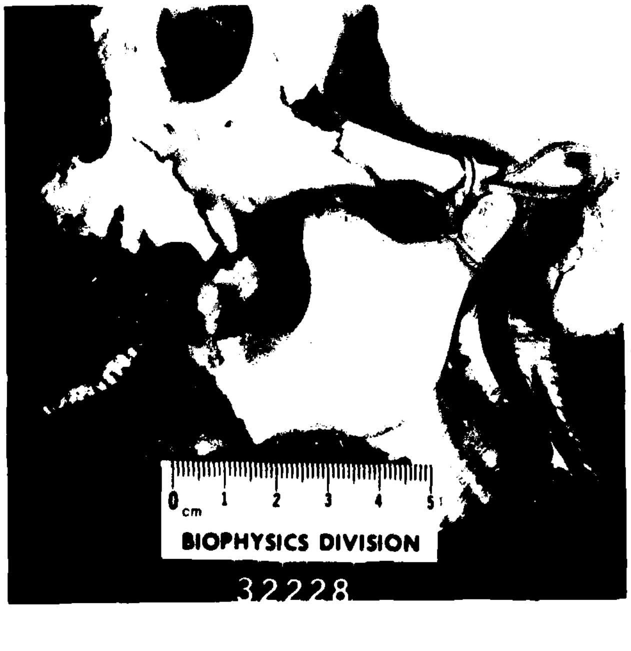

Figure 4: Sixteen grain sphere at 5746 fps impacted at mandibular symphysis, lateral view. Avulsion of anterior mandible and fractures of maxilla and maxillary molars are seen at A. Zygomatic and orbital fractures are shown in B. Fragment of target grid is shown at C.

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Figure 5: Sixteen grain sphere at 5746 fps impacted at symphysis of the mandible. Composite view. Secondary fragments of bone and teeth can be seen in the Foramen Magnum and across base of skull. (Arrows).

Figure 6: Sixteen grain sphere impacted at 7340 fps into right zygomatic complex.
Gross fracture and displacement is evident throughout the maxillofacial complex.

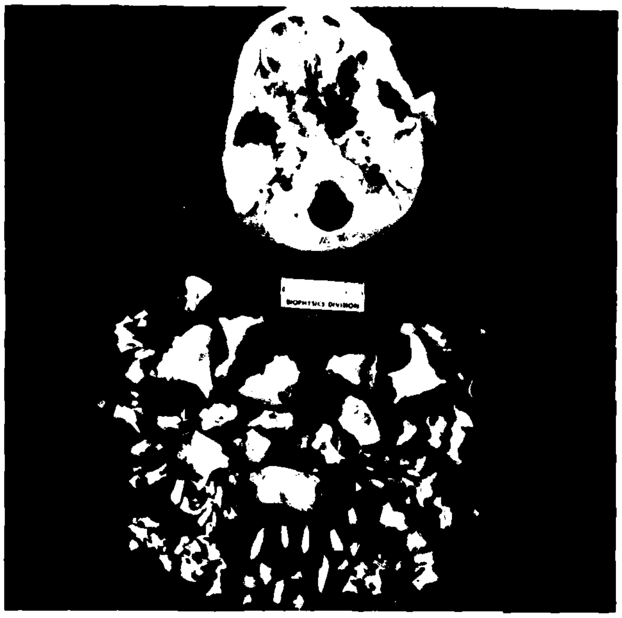

Figure 7: Sixteen grain sphere impacted at 7340 fps into right zygomatic complex.
The fractures and displacement across the base of the skull are clearly evident. The multiple fragments and secondary missiles consisting of bone and teeth are at bottom.

Figure 8: Seven grain sphere impacted into the right Zygoma at 5637 fps. Fractures of the zygoma, condyle and orbit are clearly seen.

Figure 9: Seven grain sphere impacted into the right Zygoma at 5637 fps. Fracture of the Zygoma is evident at upper left. Wound tract (arrow) is visible traversing across oral cavity to left mandible.

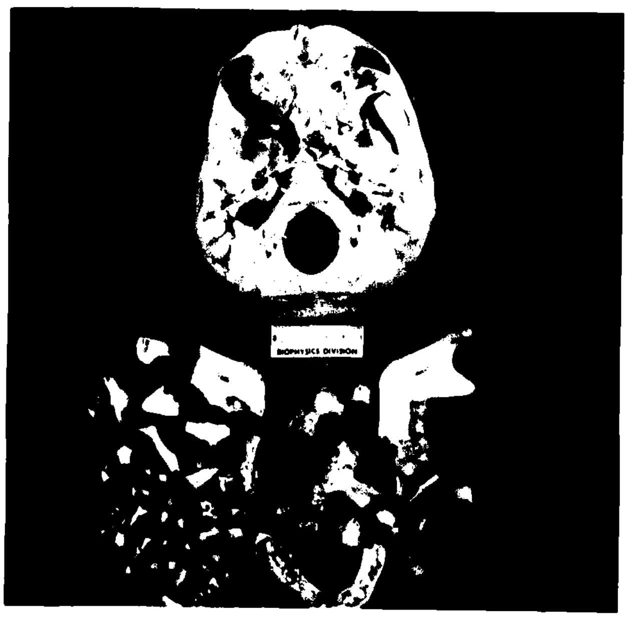

Figure 10: Seven grain sphere impacted into the right Zygoma at 5637 fps. Composite view. Multiple fragments including many small fragments within the right orbit (arrow) are clearly evident.

fragments were found across the base of the skull and within the right orbit.

Two grains impacted into the right zygoma at 5637 fps.

The right zygoma, coronoid process and articular emminence were fractured with formation of multiple small fragments, figure 11. The 2 grain missile penetrated into the oral cavity, lodging in the gelatin approximately 3 cm. lingual to the coronoid process, figure 12.

Discussion

The gelatin block firings demonstrate the soft tissue wound morphology which could result from a 55 grain bullet or missile with a speed of 6144 fps. The tremendous cavitation produces a wound and distant tissue damage much greater than that experienced with conventional speeds of 3500 fps or lower. In this study similiar mass/velocity impacts into the skull/mandible demonstrated avulsion of tissue, fractures and a large number of secondary missiles. There were at least 180 major secondary fragments of bone and teeth. The wound pathways of these secondary missiles, the cavitation due to the high velocity and the primary missile wound tract would combine to form a wound which would, in most cases, be fatal. This wound extension and contamination would be greater and encompass more tissues, contain more foreign debris and require much more complex and dedicated treatment than those produced by lower speed missiles.

The reduction of mass/velocity to 16 grains at 5746 fps still produced significant avulsion of the bony facial skeleton and caused significant radiating non-displaced fractures of the frontal bone. Again secondary missiles and contamination would have caused extensive local and distant damage to various structures and the movement of secondary missiles, especially tooth fragments, would markedly enlarge the wound size and increase the complexity and scope of treatment.

The effects of increased velocity with a constant mass (16 grains at 7340 fps) produced only slightly less tissue destruction, bone fractures and wound size as seen with the 55 grain missile at 6144 feet per second. Again, this type of wound would, in most cases, prove to be fatal.

In contrast reducing the mass/velocity figures to 7 grains and 5637 fps changed the wound morphology significantly. There was no gross tissue avulsion, although several fractures of the maxillofacial skeleton occured with minimal displacement of fragments. These large bony fragments were maintained within reasonable anatomic approximation. Small fragments did penetrate through several different structures including the foramen magnum. At this energy level and penetration site, the missile did not exit the tissue but remained against the mandible opposite the entry site. This wound, although incapacitating and possibly life threatening, would most likely allow for successful treatment. However, the success or failure might well depend upon the surgeons knowledge of the differences in morphology

Figure 11: Two grain sphere impacted at 5637 fps into the right Zygoma. Fractures of the coronoid process, Zygoma and articular eminence are clearly evident. Multiple small fragments can be seen in the area of the temporomandibular joint and infratemporal space.

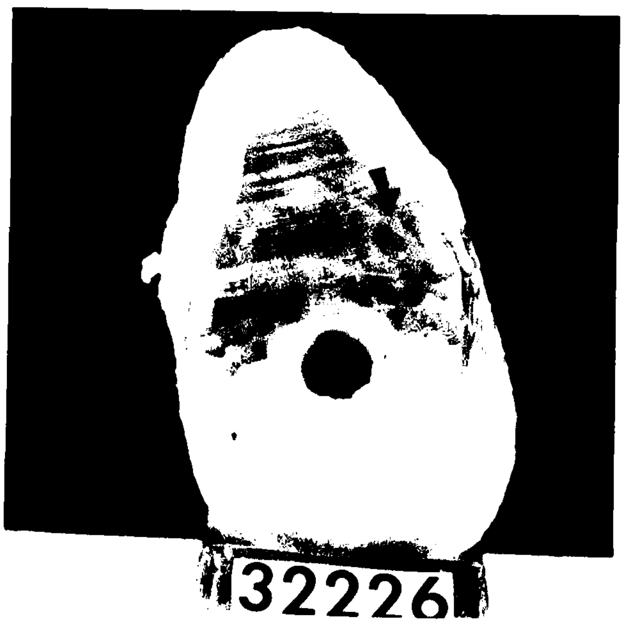

Figure 12: Two grain sphere impacted at 5637 fps into the right Zygoma.
Green stick fracture of the mandible is seen at A and the missile is identified at B.

produced by high velocity missiles.

When mass/velocity figures were reduced to 2 grains at 5637 fps, there was a marked decrease in the severity of damage with minimal fractures and few secondary fragments. Again, this small missile did not exit.

The findings of this study indicate that an increased velocity produces greater cavitation in soft tissue with an expected increase in the amount of contamination from protective gear, clothing, soil, etc. This factor would be expected to cause an increase in wound size, more distant disruptions along tissue planes, greater vascular damage, increased damage to the central nervous system and increase the number of secondary infections in comparison to conventional weaponry. A second important finding of the study is the increased numbers of secondary missiles produced by the impact of fast moving missiles on bone and teeth. This increased fragmentation would be expected to cause larger total wound size, injury to more surrounding and more distant structures, greater incapacitation and increased secondary infections. This is especially true of hits shattering the hard enamel of teeth.

These findings tend to re-emphasize the work of Mcleod who stated that debridement around the maxillofacial area requires a different approach. Similiarly, this statement from the Emergency War Surgery NATO Handbook needs restating, "From the Medical standpoint, the surgeon must know the wounding capacity of the weapons to assist in evaluating the extent of injury to achieve the most effective therapy."

In summary, this study has shown that the morphology of wounds produced by weapons systems which produce ultra-fragmentation into very small size particles delivered at very high velocities is different from conventional speed missiles and that presently accepted treatment modalities may well require alteration in order to produce optimum treatment results. This is especially true in a small compact area such as the maxillofacial complex which contains the very organs responsible for sight, smell, hearing, taste and life itself.

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References

1. Blair, V.P.: Relation of The Early Care to the Final Outcome of Major Face Wounds in War Surgery. Mil Surg 92:12-17, 1943.

2. Charters, A. Crane, and Charters, Alexander C.: Wounding Mechanism of Very High Velocity Projectiles. J. of Trauma 16:464-470, June 1976.

3. Clemedson, C.J. et al: Head Injuries Caused by Small-Caliber High Velocity Bullets, an Experimental Study. Z. Rechtsmedizin 73:103-114, 1973.

4. Converse, J.M.: War Injuries of the Face. Trans Am Acad Ophthalmol(1941) 46:250-255, May-June, 1942.

5. Dubin, H.C.: A Cavitation Model for Kinetic Energy Projectiles Penetrating Gelatin. Bal. Res. Lab Memo. Rept. 2423, 1974.

6. Kabakob, B.D. and Slepchenko, M.A.:Organization of Specialized Care for Maxillofacial Wounds. Moscow Military Medical Journal. Number 3, 19-21, 1979, pp.(a) 17, (b) 8,9.

7. Kelly, J.F. (ed).: Management of War Injuries to the Jaws and Related Structures. Washington, D.C., U.S. Govt. Printing Office, 1977, pp (a) 7, (b) 8,9.

8. MacLeod, G.H.B.: Notes on Surgery of War in Crimea. Philadelphia, J. B. Lippincott and Company, 1862, pp 198-201.

9. Maughon, J.S.: An Inquiry Into the Nature of Wounds Resulting in Killed in Action in Vietnam. Mil Med 135:8, 1970.

10.NATO Handbook, Emergency War Surgery, US Revision,Washington, D.C. U.S. Govt. Printing Office, 1975, pp (a) 10, (b) 13, and (c) 9.

11.Schwartz, L.L.: The Development and the Treatment of Jaw Fractures. J. Oral Surg. 2:193-221, 1944.

12.Tinder, L.E., Osbon, D.B., Lilly, G.E., Salem, J.E., and Cutcher, J.L.: Maxillofacial Injuries Sustained in the Vietnam Conflict Mil Med. 134:668, 1969.

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